This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

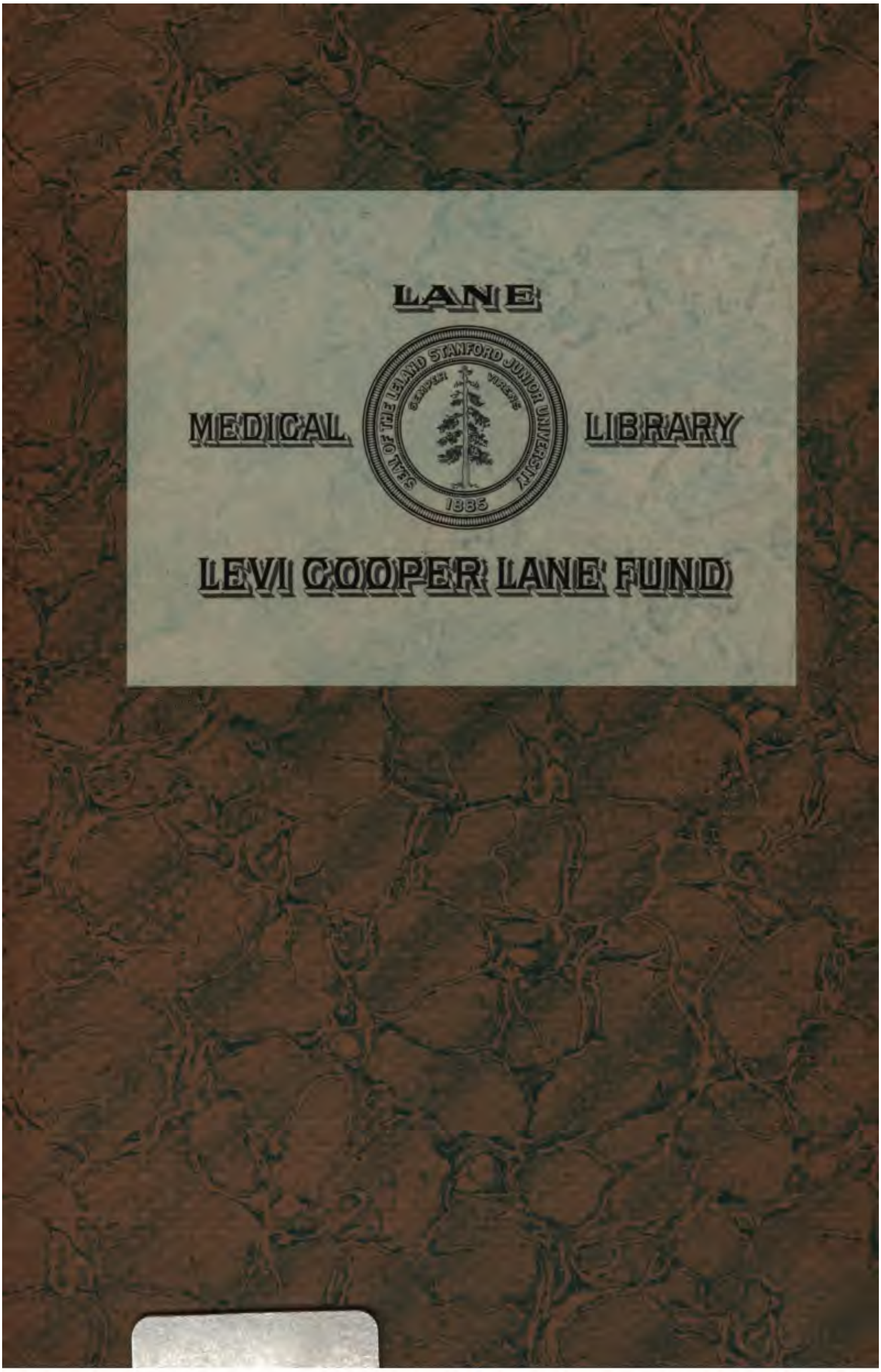
Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

2 45 0423 0781

Russell, H. L.

A bacterial rot of cabbage and allied plants. 1898

Y31
W8E1
Nº65



LANE

MEDICAL LIBRARY

SEAL OF THE LELAND STANFORD JUNIOR UNIVERSITY
SEMPER VIRENS
1885

LEVI COOPER LANE FUND

Gaylord Bros.
Makers
Syracuse, N. Y.

Wis. Bull. No. 65.

UNIVERSITY OF WISCONSIN.

Agricultural Experiment Station.

BULLETIN NO. 65.

A BACTERIAL ROT OF CABBAGE AND ALLIED PLANTS

by H. L. Russell.

MADISON, WISCONSIN, FEBRUARY, 1898.

☞ *The Bulletins and Annual Reports of this Station are sent free to all residents of this State upon request.*

LANE LIBRARY

D

UNIVERSITY OF WISCONSIN.

AGRICULTURAL EXPERIMENT STATION.

BOARD OF REGENTS:

STATE SUPERINTENDENT	EX OFFICIO.
PRESIDENT OF THE UNIVERSITY	EX OFFICIO.
JOHN JOHNSTON, STATE AT LARGE,	PRESIDENT
B. J. STEVENS, (2d District),	CHAIRMAN EXECUTIVE COMMITTEE
STATE AT LARGE,	H. W. CHYNOWETH
1ST DISTRICT,	OGDEN H. FETHERS
3D DISTRICT,	W. A. JONES
4TH DISTRICT,	GEORGE H. NOYES
5TH DISTRICT,	JOHN R. RIESS
6TH DISTRICT,	FRANK CHALLONER
7th District,	WM. P. BARTLETT
8TH DISTRICT,	ORLANDO E. CLARK
9TH DISTRICT	J. A. VAN CLEVE
10TH DISTRICT,	J. H. STOUT

SECRETARY, E. F. RILEY, MADISON.

Station Committee.

REGENTS JONES, CLARK AND FETHERS.

OFFICERS OF THE STATION:

THE PRESIDENT OF THE UNIVERSITY.

W. A. HENRY,	DIRECTOR
S. M. BABCOCK,	CHIEF CHEMIST
F. H. KING,	PHYSICIST
E. S. GOFF,	HORTICULTURIST
W. L. CARLYLE,	ANIMAL HUSBANDRY
F. W. WOLL,	CHEMIST
H. L. RUSSELL,	BACTERIOLOGIST
E. H. FARRINGTON,	DAIRY HUSBANDRY
J. A. JEFFERY,	ASSISTANT PHYSICIST
J. W. DECKER,	DAIRYING
ALFRED VIVIAN,	ASSISTANT CHEMIST
LESLIE H. ADAMS,	FARM SUPERINTENDENT
IDA HERFURTH,	CLERK AND STENOGRAPHER
EFFIE M. CLOSE,	LIBRARIAN

FARMERS' INSTITUTES.

GEORGE McKERROW,	SUPERINTENDENT.
HARRIET V. STOUT,	CLERK AND STENOGRAPHER.

General Offices and Departments of Agricultural Chemistry, Animal Husbandry, Bacteriology, Farmers' Institutes and Library, in Agricultural Hall, near University Hall, on Upper Campus.

Dairy Building and Joint Horticultural-Physics Building, west end of Observatory Hill, adjacent to Horticultural Grounds and Experiment Farm.

Telephone to Station Office, Dairy Building and Farm Office.

Y31
W8E1
no. 65

A BACTERIAL ROT OF CABBAGE AND ALLIED PLANTS.

H. L. RUSSELL.

I.

GENERAL SUMMARY.*

A great many of the parasitic diseases of plants have been known for many years, but now and then an apparently new malady makes its appearance, sweeping through sections of country, leaving devastated fields in its wake. Such is the case with the cabbage rot, a disease whose nature has not hitherto been thoroughly recognized, but one which has made serious inroads in different localities throughout the state.

While the disease is more important in its relation to cabbage culture on account of the relative amount of this crop grown, it also affects a number of allied species that belong to the same genus. Besides cabbage and cauliflower, kohl rabi, kale, brussels sprouts, broccoli and collards are attacked by it and to a lesser extent it develops in turnips, rutabagas, winter radish and other closely related varieties. The latter group of plants is, however, much less susceptible to the disease, and unless the climatic conditions are unnaturally favorable, the disease makes but little headway in these species.

CHARACTER OF THE DISEASE.

The disease assumes a variety of appearances dependent upon the organ attacked, the stage of the disease, etc. Usually in cabbages it begins to make its appearance on the edge of the leaves. More often the lower outer leaves are the first to succumb, but at times the larger number of leaves of the whole plant indicate a diseased condition. Close observation will show that the disease in the early stages stands in direct relation to the veins that course through the blade of the leaf and terminate in the outer margin. As it progresses the affection works its way down the veins into the midrib, then into the leaf stalk and finally into the main stem of the plant. When once it has established itself in the main stalk it spreads rapidly through the whole plant. Traveling as it does through the veins

---

*The above summary gives the essential details that are of purely practical interest. The data from which these conclusions are drawn as well as a consideration of the more scientific and technical studies follow this summary (page 10).

9316

and bundles of the plant, it seriously interferes with the channels by which the water is distributed to the tissues of the leaf. This combined with the actual invasion of the leaf tissue with the specific cause of the disease causes the leaves to wilt, turn yellow, dry up, and become thin and parchment-like in texture. The veins and fibrous strands that course through the plant are usually blackened and often these alone are affected, the contiguous succulent tissues remaining apparently unchanged for a time at least. Such are the changes that occur in the plant as it first appears in the field. Frequently the affected plants may also be invaded by other rots that cause a wet stinking decomposition, which completely destroy the crop, as is shown in Fig. 1. Sometimes the disease may attack only one side of the plant, in which case the affected side appears dwarfed.

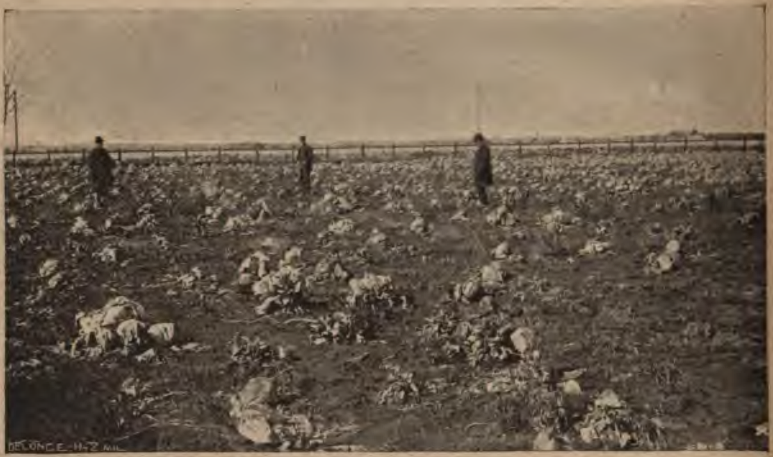


FIG. 1.—A field of cabbage at Racine, Wis., devastated by the rot. Not a single head harvested from the entire field.

A great deal of loss is frequently occasioned by the storage of cabbage during the winter where no external symptoms of the rot were apparent when crop is first placed in store. In such cases the head when cut open vertically will show a blackened area following the course of the leaves of the head. The rot spreads from leaf to leaf within the head until the whole interior is often decayed, while the outside is perfectly healthy (Fig. 2). A close inspection of the stem of such cabbage heads will generally show a blackened spot. In selecting crop for storage all cabbages that show even the tiniest blackened specks in the tissue of the stem should be thrown out as this symptom indicates that the disease has worked its way into the main stalk where further development is possible. Such rejected heads may be suitable for immediate consumption but it is a waste of space to put them in storage.

LOSSES OCCASIONED BY THIS DISEASE.

In the southeastern part of this state, in Kenosha and Racine counties, the soil seems to be particularly adapted to cabbage raising, and this business has been rapidly extending its boundaries for some years. This disease appeared first in this section in 1890 but was not troublesome until 1893. In 1895 the affected area was greatly increased, and in 1896 the losses were even greater, in many cases growers losing their entire crop. The estimated loss in this region alone was placed by experienced growers from $50-$60,000. During the last season, losses have been less severe.

Losses have also been considerable in other parts of this state as well as in other cabbage growing regions, as Michigan and NewYork.

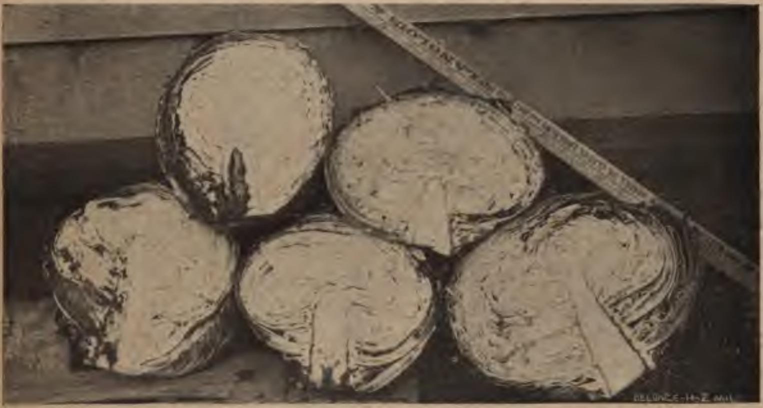


FIG. 2.—Cabbage showing disease in the heads. The black streaks up the central stem, and separate leaves of the head, indicate the progress of the disease. These cabbage heads were apparently sound from external appearances.

CAUSE OF THE DISEASE.

Before a rational method of treatment can be worked out for any disease, it becomes imperative that the real cause of the trouble should first be found out, and then, if due to a living organism, the conditions determined under which the parasite lives and develops. The manner in which the disease spreads in the field indicates quite conclusively its infectious nature. One can frequently observe a plant that may be affected soon after it is transplanted. Later in the season a number of contiguous plants will come down with the disease while the original source of the trouble may have often died to the ground.

Conclusive proof of the real cause is, however, shown by isolating the various organisms from the diseased tissue by bacteriological methods and then inoculating healthy plants with pure cultures of the various germs. This we have done in hundreds of instances and the inoculated plants showed the same general symptoms that are to be observed under fiel conditions. The germ causing this disease belongs to the bacteria. It is a well characterized form that grows luxuriantly in artificial media, producing the disease readily when inoculated into healthy, susceptible plants. The same germ produces a similar rot in turnips, and was very briefly described by Pammel in 1895, but he did not note its relation to cabbage and cauliflower which are much more susceptible and in which the disease occurs in a very much severer form. Its full life history in all of its relations has not been worked out until this year. (In this connection see foot note † on page 13.)

HOW THE DISEASE GAINS AN ENTRANCE INTO THE HOST PLANT.

We have already noted that the disease makes its first appearance generally on the edges of the leaves. Occasionally the first point of invasion seems to be in direct connection with insect wounds. Where the plant membranes are ruptured the conditions are such as to permit an easy entrance, but close inspection will fail to reveal any such wounds on the edges of the leaves. Neither does the germ find its way into the plant through the root system. In badly diseased plants, the roots may show black spots in cross section but in such cases it has worked its way down from the stem of the plant. How then does the germ find its way into the leaf?

If we examine the diseased spots in an early stage it will be noted that the malady begins at the blunt teeth on the margin of the leaf and from here spreads down the leaf by way of the fine veinlets. A microscopical examination of the leaf at this point shows tiny permanent openings called water pores. Through these openings the water that comes from the root system escapes in part. Ordinarily it passes off in the form of vapor, but if the air is humid, the exuded water collects in tiny droplets at the mouths of these water pores.

These water beads are especially frequent in the morning, and by most people are supposed to be dew. In the chilly nights of early autumn the conditions especially favor their formation as a lowering of the temperature causes the air to become more nearly saturated with moisture. If the ground is deficient in moisture these water beads may not be formed even though atmospheric conditions are favorable.

During such times the disease germs that are being blown about the field by the wind are caught in these drops. In these they are able to develop and as they are actively motile, they work their way into the plant through these uninjured water pores. Not only is this theory of their entrance a plausible one from the appearance of the disease in the fields but the same has been demonstrated as a result of the artificial inoculation of these water beads and subsequent contraction of the disease at these infected points. It is for this reason that the disease makes faster headway in wet than in dry seasons.

INFLUENCE OF CLIMATE ON THE DISEASE.

In some sections of country where cabbage is raised on the same ground year after year the disease varies much in intensity. In Wisconsin the season of '96 was extremely severe while the losses in '97 were relatively small. The reason for this is that climatic conditions exert a profound effect upon the susceptibility of the host or rather the ease with which the disease germ penetrates the plant.

As noted above, atmospheric conditions that favor the formation of water beads therefore have a direct influence on the severity of the disease.

Then too the disease spreads more rapidly in vigorous, rapidly developing plants than in those whose growth is retarded by insufficient supply of water, so that in seasons in which the rainfall is abundant the disease is likely to be more prevalent and more destructive than otherwise.

DOES THE DISEASE GERM WINTER OVER IN THE FIELDS?

There can be no question but that the disease germ is distributed by means of the wind and possibly to some slight extent by insects. Another pertinent question is, how the virus of the disease is able to live over winter? The cold of winter is popularly supposed to destroy most forms of germ life, but such is rarely the case. In nearly all instances bacterial growth is prevented by low temperatures but such do not effectually destroy these germs. Cultures of this organism kept frozen for considerable periods, grew luxuriantly when thawed out and placed under favorable growth conditions. These organisms readily retain their vitality in the old diseased stumps and rotten heads that are left in the fields, and in all probability are able to live in the soil itself as the germ is able to thrive luxuriantly outside of the living plant.

TREATMENT OF THE DISEASE.

A bacterial disease is difficult to treat successfully after it has once gained a foothold. A disease of this character usually develops internally, and unless recognized at the outset, it generally makes such headway as to render remedial measures futile. Not so with reference to means of prevention. These can often be applied at such times as to prevent the disease organism from gaining a foothold. This, however, can only be done after a thorough study of the disease organism has been made in its relation to the host plant.

The following restrictive measures are based upon a rational knowledge of the disease organism and how it spreads.

Destruction of the disease germ.—Just to the extent that disease tissue can be removed, just to that extent are the elements of contagion diminished. Although sunlight as well as drying exert a powerful effect on the vitality of the organism, these agents cannot be relied upon for the destruction of diseased tissue. So much refuse material, leaves, stumps, etc., remain in the fields after the crop is harvested that the opportunity of thoroughly seeding the ground with disease germs in case the crop is affected is exceptionally favorable. While it undoubtedly would be advantageous to get rid of this decaying and diseased material, it is a question whether the advantage gained would compensate for the trouble and expense of the same unless the method was generally pursued throughout a large section.

Rotation of crops would also be helpful in ridding the ground of the specific organism. Where cabbage is planted on the same soil year after year, if climatic conditions favor the development of the trouble, the fields frequently become badly infested with this particular organism, inasmuch as it is able to exist in the soil over winter.

Control of conditions favoring infection.—While this disease is caused by the presence of a specific bacillus, the severity of its attack is very largely dependent upon external conditions, some of which are capable of being controlled in part. It seems very probable that the disease is sometimes introduced into the plants by insect puncture when the seedlings are in the seed bed. If this should prove to be true, it ought to be a relatively simple matter to check such ravages where the area to be covered is so limited as in this case.

Care should also be taken not to plant cabbage on very low soil where the soil moisture will produce too luxuriant a growth as well as too copious an exudation of water from the leaves. Where irrigation is practiced water should not be added to the soil when the atmospheric conditions are such as to prevent an escape of the moisture in the form of vapor.

Checking development of disease after infection.— Inasmuch as *B. campestris** generally establishes itself in the plant through the water pores, and as considerable time elapses from the first evidences of the disease until it has worked its way down into the main stem, it is possible to hold the disease in check in its early stages by a removal of the affected organs. One can readily determine whether the leaf is diseased or not by examining the cross section of the stalk. If blackened near the union of leaf and stem even if small specks appear in the fibrous strands, the disease organism has undoubtedly entered the stem of the plant. If such has happened, nothing can be done to further check its progress. Such plants should be pulled up and destroyed entirely. If thrown on the ground the diseased tissues dry and the bacilli of the disease are then readily distributed by the winds.

If close watch is kept for the early appearance of the disease, the removal of the affected leaves is a matter of small moment.

**Bacillus campestris* is the scientific or technical name of the species of bacteria that is the real cause of this disease.

Gaylord Bros.
Makers
Syracuse, N. Y.

Such a method of treatment necessarily consumes some time but it can be done by cheap labor. With a crop worth from $75 to $150 per acre, considerable labor can well be expended if attended with any degree of success. The amount of labor necessary to carry out this restrictive measure will vary with the intensity of the disease, but a man could easily cover several acres a day.

The feasibility of this method was demonstrated not only last year experimentally but also under commercial conditions. By removing the affected leaves at intervals during the months of August and September, the disease was held in subjection and a good crop secured while control fields were badly affected.

II.

DETAILED STUDIES ON THE FOREGOING DISEASE.

The disease here described first came to the writer's attention in July, 1895. It was found in Columbia county, Wis., in a small garden patch of cabbage that was planted on rich low ground. The disease made its appearance in the stalks of the lower leaves, causing a destructive rot but only affecting a few of the plants. An examination of the cross section of the leaves showed that the disease was distributed by means of the fibrous strands that course through the leaf stalk and branch off into the smaller veins of the leaf blade. A preliminary examination showed the affected tissues to be swarming with bacteria and from the general character of the disease in the plant, the inference was made that it was due to the inroads of a bacterial parasite. By means of culture methods two predominant forms were separated from the diseased tissue. The attempt was then made to artificially infect healthy growing cabbages by inoculating them with cultures of these two organisms, also by introducing bits of diseased tissue into the healthy plants but as the cabbage plants used for these experiments were old, infection did not readily occur. In a number of instances infection experiments succeeded to a certain extent with a pure culture of one organism and also with bits of diseased tissue, but the development of the disease was only slight and did not fully accord with the original affection. The blackening of the fibro-vascular bundles was, however, produced, and in this important particular the artificial infection corresponded with the natural appearance of the disease.

With the view of determining its distribution, etc., a brief preliminary note* was presented in August at the meeting of the American Association for the Advancement of Science.

The only reference that was found in regard to a bacteriosis of cabbage that in any way agreed with this disease was a brief note by Garman† in 1890. In his disease the cabbage heads often rotted on the inside. He makes, however, no mention of the earlier affection in the fibro-vascular strands. By means of cultures, he isolated two organisms, one of which was in all probability the real cause of the disease, but infection experiments with cultures of these were indecisive. Pammel undoubtedly first discovered the organism causing this disease in 1892, but he did not associate it in any way with the present malady we are considering in cabbage. A discussion of his results will be taken up again under the description of the organism. Correspondence with various botanists elicited the information that a disease of this character affecting cabbage and cauliflower had been noticed at times before, but no systematic attempt had been made to study the problem from a scientific standpoint.

---

*Report of Amer. Ass'n for Adv. Science, 1895, p. 193.

†Ky. Expt. Stat. Rept., 1890, p. 43.

In the season of 1896 search for the disease was again made. The field where it had been first observed was replanted to cabbage but no outbreak occurred. In September, the experimental fields of cauliflower at the university were however found to be diseased. The onset of the disease had been rapid and when the writer first saw the patch, the trouble showed severely in places, although it was not extensively distributed throughout the field. The general appearance of the disease especially with reference to the blackened condition of the bundles agreed with that found in cabbage the preceding year.

ISOLATION OF THE DISEASE-PRODUCING ORGANISM.

Attempts were again made to isolate the organisms in the diseased plants and this time pure cultures of a bacillus producing a yellow pigment were found in the affected tissue. From a number of different plants in this affected field, cultures were made with the same result. Before plants could be grown for inoculation purposes, notice was received from Dr. J. J. Davis, of Racine, Wis., that a very destructive rot was devastating the cabbage region in Racine and Kenosha counties. On Oct. 2, we received from Dr. Davis samples of diseased leaves and from these were isolated the same organism that had already been found in the affected cauliflower at Madison. This left but little doubt as to the relation that the yellow pigment-forming bacillus bore to the disease in both cabbage and cauliflower. Artificial inoculation experiments were made in both cabbage and cauliflower with organisms from six different sources that gave positive and uniform results. The inoculation was usually made by puncturing the stem of the plant or base of the petiole of the leaf with a needle that had previously been dipped in a pure culture of the isolated organism. The disease manifested itself generally in the course of a few days, spreading through the fibro-vascular elements of the leaf, in both directions. The appearance of the artificially induced disease could leave no possible doubt as to its identity with the natural disease, but in order to settle this point beyond all question cultures were made from the artificially diseased tissues and the same organism isolated. This proved conclusively the causal relation in which the specific bacterial organism stood to the disease in the host.

HISTORY OF THE DISEASE IN RACINE AND KENOSHA COUNTIES, WISCONSIN.

The disease has assumed such serious proportions in this region that the following historical notes are submitted as of interest. The growing of cabbage for the general market has become within the past decade an important industry in these counties. In addition to the local demand in the manufacturing cities of Racine and Kenosha large quantities of cabbage are held in storage to supply the spring trade. The climatic and soil conditions in this vicinity seem to specially favor this crop and the acreage planted has been steadily increasing of late years until the introduction of this disease. The main center of the industry is along the lake shore for a distance of eight to ten miles and westward for a distance of six miles. The land, which is usually of a sandy black loam, is very fertile and has a clay subsoil. To Mr. W. J. Hansche, one of the leading growers and buyers of cabbage in this vicinity, I am greatly indebted for the following facts relative to the early history of the disease, as well as other valuable information upon this subject. The trouble was first noticed in 1890, when a single field of cabbage developed this peculiar rot. The next year it disappeared and nothing further was noted until 1893, when it reappeared, two or three acres being destroyed. The area of the disease became gradually enlarged until in 1895, nearly one-half the acreage planted was more or less severely affected. Last season (1896) the disease was likewise very destructive, many growers suffering a total loss. The estimate for the two counties was placed at from 50,000 to 60,000 dollars. The disease was most severe near the lake shore, but it appeared in several places that had not previously been affected. This year the disease made its appearance somewhat later than usual, the first evidence of it developing in late cabbage as late as the latter part of August. The prolonged drought this fall has retarded its spread materially and the leading growers estimate the damage may be from 5 to 25 per cent. of the crop. An examination of the affected district shows that the disease is as widely spread as ever but has been held in subjection by the unfavorable climatic conditions.

POPULAR OPINIONS AS TO THE CAUSE OF THE DISEASE.

The cause of the disease has been a subject of much conjecture among the growers in this district. There is a strong prevailing idea that it is associated with the seed used. Previous experience seemed to indicate that cabbage grown from imported seed was less likely to be attacked than that coming from domestic seed. This notion could not be confirmed last year; in fact the disease was much less severe in the home grown stock than in the imported seed. New land seems to be affected quite as readily as old fields; tile-drained as much as surface-drained land. It is, however, noticeable that the trouble is more severe in low wet land than on fields containing less soil water. The fields are necessarily heavily manured as the crop rapidly exhausts the fertility of the soil. In most cases the manure comes from the Chicago stock yards. According to the experience of the growers, fields fertilized with fresh manure are more subject to the disease than where old manure is used.

It is evident from the history of the development of the disease in this section that the trouble is one of recent introduction and that the cause is generally unknown.

GEOGRAPHICAL DISTRIBUTION OF THE DISEASE.

Geographically considered, this disease is undoubtedly wide spread. Garman first observed it in Kentucky in 1889, and he informed the writer in 1895 that " this, or a similar malady is very destructive in the southern states." Chicago commission men say that the disease is widely distributed throughout the north-west. Cabbage received from Clyde, O., Three Oaks, Detroit and Saginaw, Mich., were affected with it. It was also reported last season in Wisconsin from several different localities.

Prof. Pammel reports it from Ames, Iowa, and in the East, especially New York, it has proven a serious pest. Through Prof. F. C. Stewart* of the New York State Experimental Station, I learn of its wide distribution in that state. On Long Island considerable cabbage is grown for seed. Extensive losses are occasioned there by the development of the disease in plants held over the winter for seed. The cabbage and cauliflower market gardens of Rochester, Geneva and the western part of that state have also been afflicted with it. Prof. Jones of the Vermont Station testifies to its abundance in that state.

The above notes indicate its wide distribution. It would seem strange that in a disease so widely spread so little attention should be paid to the cause of the malady, but aside from Garman's brief note and the preliminary paper presented to the Amer. Assn. for Adv. of Science by the author, no reference has hitherto been made to its presence in cabbage.†

DESCRIPTION OF ORGANISM PRODUCING THE DISEASE (*Bacillus Campestris*, Pammel).

Although this organism has not heretofore been connected with the cabbage and cauliflower rot, it is without doubt identical with that described by Pammel in 1895 as *Bacillus campestris*, the cause of the rutabaga rot.‡

Pammel's description of his organism is however too brief to enable close comparisons to be drawn. As to its pathogenic nature, he only mentions it in connection with rutabagas and turnips, making no reference to its action on other species of the genus Brassica. He also distinctly states that it does not liquefy gelatin, a characteristic that does not agree with our studies of the organism causing the cabbage rot. When grown on strongly acid gelatin, the liquefying power of the organism is greatly diminished, so that liquefaction does not occur for a considerable period. This probably accounts for Pammel's statement. Although attempts were made to secure from Prof. Pammel microscopic slides or cultures of his rutabaga organism, I was unable to obtain these for further comparison. The relation of the rutabaga organism to the cabbage disease evidently was not perceived by Prof. Pammel until long after his work on the rutabaga rot was done, for he wrote me in Nov. 1896 in answer to inquiries that the cabbage and cauliflower disease referred to had been observed by him at Ames, Iowa, "but he had not worked it up." The description as given by him in the above paper is so meagre that it has been thought best to detail rather fully the morphological, physiological and culture characters, in order that further confusion may be obviated. The following description submitted, has for the most part, been prepared under my direction by Mr. H. A. Harding, now Research Fellow in this department.

---

*I wish especially to acknowledge my indebtedness to Prof. Stewart who has so kindly placed at my disposal the data he has collected in New York pertaining to the disease.

†Since this work was practically completed there has appeared in the Centralblatt für Bacteriologie, Band 3:284, 408, 478 (1897), an article by Dr. E. F. Smith, entitled "Pseudomonas campestris (Pammel), the cause of brown rot in cruciferous plants." This work was begun subsequent to our own and with the full knowledge that we were engaged in working on this disease, but the publication of Dr. Smith's paper antedates the appearance of this bulletin which has been delayed for nearly five months in passing through the press by circumstances over which the writer had no control. The practical unanimity in all essential particulars in these respective papers strengthens the views advanced.

‡Bul. 27, Ia. Agrl. Expt. Sta., pp. 130-134. (1895.)

By H. A. Harding.

In determining physiological and culture characters, the temperature at which the organism is grown, the age of the culture, and the length of time it has been cultivated under artificial conditions, are all factors that must be taken into account, as a variation in these conditions frequently exert a profund influence on the character of the culture.

If our experments for the past year or more can be relied upon, the vitality of the organism is decreased by long cultivation as is shown by its lessened resistance to heat and dessication and by its slower rate of liquefaction of gelatin. However, the pathogenicity of the organism at the end of eight months was fully equal to that of a freshly isolated germ.

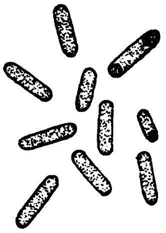


FIG. 3.—Microscopic appearance of *B. campestris*, homogeneously stained with Loeffler's methylen blue. (Leitz, obj. one-sixteenth inch, 4 ocular.)

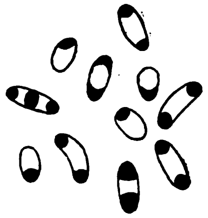


FIG. 4.—Microscopic appearance of *B. campestris*, stained with carbol-fuchsin. Note the somewhat thicker appearance of cell and distribution of stain in spots, as compared with fig. 3.

MORPHOLOGY.

A morphological examination can best be made from a neutral agar slope grown at 25-30° C. The disease germ is a short bacillus of somewhat variable size, ranging from 1-2 μ long by 0.4-0.6 μ broad with slightly rounded ends. The cells are usually isolated but when growth is rapid, short chains consisting of two to eight segments are common (Fig. 5), and in exceptional cases, the conditions of which are not well understood, long filaments are formed during the first twenty-four hours. Spore-form action does not occur.

In 16–48 hour old cultures, the organisms are endowed with a very lively darting and rotary motion. This movement becomes less noticeable with increasing age, and in cultures six to ten days old nothing but a lively Brownian motion remains.

No distinct capsule has been demonstrated but the unstained cell wall is rendered very distinct by contrast when stained with methylene blue. Adherent masses of zoogloea are formed in liquid cultures (bouillon, liquefied gelatin, and milk).

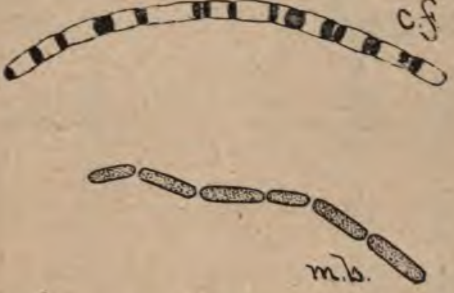


Fig. 5.—Filaments of *B. campestris*. C. f., stained with carbol-fuchsin; m. b., stained with methylen blue.

Relation to stains.—The cells in young cultures (16–24 hours old) are homogeneously and readily stained with Loeffler's methylene blue, or an aqueous solution of fuchsin. As the culture becomes older and many of the bacterial cells degenerate, the methylene blue stains less readily, until at 20 days it is effective only when its action is intensified by heating or long application. Ziehl's carbol-fuchsin solution stains the cell readily at all times, but the coloring matter is usually irregularly absorbed as indicated in figure 4. In many cases the poles are deeply stained leaving a central unstained zone. The cell wall is faintly tinted thus uniting the polar areas. With Gram's stain the organism is decolorized.

CULTURE CHARACTERISTICS.

The media used for the determination of culture characteristics unless otherwise stated, was made neutral to phenolphthalein by sodium hydroxide.

Agar.— On agar plates the organism produces a characteristic growth, especially at 25° C., colonies usually attaining a size of one to two mm., although on sparsely seeded plates they may be several times as large. To the naked eye, by transmitted light, these are thin, moist, shining and quite translucent; by reflected light more opaque. In color they are light yellow with an olive tint.

Under low power of microscope (Leitz, 3 oc. and 3 obj.) surface colonies appear thicker in center, often having a dense, sharply defined "nuclear" area. Under this power, the colony may usually be differentiated into the following zones:

1. A central circular area, generally homogeneous in texture and yellow in color, that usually embraces the darker spot or "nucleus."
2. This is surrounded by a zone of varying width that is coarsely granular and usually darker in color than the central zone.

3. An outer zone forming an area that is either homogeneous or very finely granular. Although these zones vary in width they are usually quite sharply defined, especially in the younger colonies. In old cultures crystals often appear imbedded in the growth mass. Deep colonies are lenticular or irregular, varying from ½ to ¾ mm. in diameter. They are usually darker in color, quite granular, and show a tendency to form concentric rings.

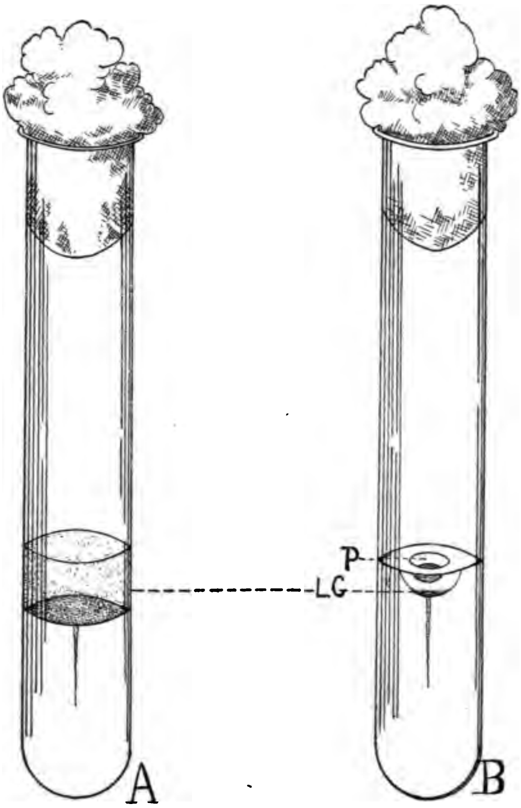


FIG. 6.—Gelatine tube cultures of *B. campestris*. B, 10 day old culture. P, pit formed in liquefied gelatin by evaporation of volatile products; L. G., liquefied gelatin rendered fluid by action of enzymes.
A, later stage of same culture (1 mo. old), upper portion of gelatin entirely liquefied.

Agar streak cultures show a very characteristic appearance; they grow luxuriantly, appearing as a faint yellow streak in about two or three days at about 25° C. At first the growth is elevated but later extends laterally, having a somewhat irregular border, the color gradually assuming in old cultures a rich golden yellow, and at the same time becoming more translucent. In cultures two or three months old, numerous crystals are formed in the matrix of the growth mass. Old cultures are frequently covered with small papillæ that are formed by secondary colonies developing in contact with the above crystals on the surface of the former growth.

Gelatin (10 per cent. neutral peptone). In plate cultures the organism grows slowly at ordinary room temperature — (16-22° C.), colonies appearing in the course of several days. Surface colonies attain a size of about 1 mm. and are moist, shining, raised, and of a light yellow color. Under low power they are circular with a sharply defined edge and regular contour. The colonies are marked by a central dark area that is bounded by a lighter zone. In texture the colony is finely and uniformly granular with radial streaks appearing in some cases.

Deep colonies are circular, of sharp outline, darker in color than surface growths, and show a tendency toward formation of concentric rings. No liquefaction of gelatin, as a rule, is evident on plate cultures until the same is from 12 to 15 days old, when the colonies begin to liquefy, the saucer shaped depression that is made being partially filled with transparent liquid gelatin.

In stab cultures in the course of a few days growth appears as a faint streak along entire needle track spreading slightly at the surface. In a week or ten days a restricted liquefaction develops around the surface growth and a deep pit is formed by the evaporation of volatile decomposition products. The liquefied mass spreads laterally, the original surface growth remaining on top of the fluid gelatin unless displaced by shaking the culture, in which case it sinks to the bottom. The liquefied gelatin remains clear, a copious precipitate collecting at bottom of the liquefied mass. Peptonization of the gelatin in the tube progresses in horizontal layers, the speed of liquefaction diminishing with age. Several months are required to entirely digest the gelatin.

Some variation in rate of liquefaction is observed between freshly isolated and old cultures of this organism, those recently isolated liquefying more rapidly.

On *potato* it shows a very characteristic growth; at first it is a light yellow, but with increasing age, it changes to a cadmium yellow, and in old cultures to a golden brown. It grows rapidly and abundantly, presenting a moist, shining mass of pasty consistency. In eight to ten days the entire surface of the potato is covered, the growth mass often flowing off and covering the bottom of the dish. The reaction of the potato is changed from markedly acid to faintly alkaline by the organism and this alkalinity extended throughout the potato.

Cultures on cruciferous substrata.— Cabbage, cauliflower, ruta-baga, winter radish and turnip were also used as culture substrata. On these the organism produced a moist, shining, transparent slimy mass that was so luxuriant in its development as to flow off into the bottom of the tube in the course of a few days. These cultures showed varying shades of yellow, but in no case was the color as bright and pronounced as on agar slopes. All had the peculiar odor that is common to decomposing cruciferae. In the case of the white winter radish and the cauliflower the substratum became markedly brown in a few days.

Peptone beef bouillon (neutral in reaction), is rendered slightly turbid in two to six days, a yellow deposit adhering to wall of glass at surface; this is easily displaced and sinks to the bottom of tube. No true pellicle is formed. The turbidity which at first is very uniform clears up in time, a granular yellow precipitate collecting at bottom. The addition of glucose or lactose sugar to the bouillon does not change the appearance of cultures.

In *litmus milk* at 25° C., in the course of ten days, the faint blue of the medium is changed to a pink but no well marked curd is produced. The first noticeable change in the consistency of the milk is in the appearance of a layer of whey on top of culture. The casein is gradually digested, and in the course of a month, a yellow ring of zoogloea is formed on the surface of the liquid in contact with the glass, a similar yellow deposit collecting at the bottom of the culture, while the liquid assumes a yellow tint.

Vegetable juices.— Cabbage bouillon was prepared by boiling 200 gr. of cabbage leaves and making the filtrate up to 500 cc. This naturally acid medium was divided into three parts, one of which was rendered still more strongly acid while the other two were made neutral and alkaline to phenolphthalein. No difference in growth was observable in these solutions but in all three lots *Bacillus campestris* grew better than in the neutral beef peptone bouillon, producing a more flocculent turbidity and rarely a faint trace of surface pellicle.

Cauliflower bouillon was also prepared in the same way with essentially the same results.

Fermentation tubes.—At 22°C. in neutral beef extract peptone bouillon with 2 per cent. glucose, the fluid was rendered uniformly turbid in two days in bulb and connecting piece, but no growth occurred in closed arm, neither was any gas produced in cultures kept for four weeks. The turbid growth was sharply defined at the bottom of the closed part of the tube from the clear fluid above. Later the turbidity collected on the bottom of tube. No pellicle was formed on surface of the fluid.

In peptone media to which 2 per cent. lactose was added, similar growth characters prevailed, no gas being formed in any case. This indicates the obligate aerobic characteristics of the organism.

Relation to oxygen.—The aerobic characteristics of the organism are demonstrated by the way it behaves in the fermentation tube. In the deeper layers of gelatin or agar, growth is invariably very slight. The formation of proteolytic enzymes as seen in the liquefaction of gelatin occurs only where oxygen supply is abundant. Hence, continued liquefaction in old cultures is very slow. Cultures made in Buchner tubes on agar slopes with pyrogallic acid failed to develop.

Products of metabolism.—As a result of metabolic activity several characteristic products are formed.

a. Pigment.—At ordinary temperatures in darkness as well as in light, a yellow pigment is produced, the shade of which varies with the substratum, the age of the culture, and the length of time the germ has been grown under saprophytic conditions. This coloring matter is soluble in ethyl and methyl alcohol; is unchanged in glycerine, darkened in carbon bisulphide xylene, gasoline, and chloroform; slowly destroyed in dilute acetic acid, and destroyed in sulfuric ether, dilute HCl, H_2SO_4, HNO_3.

b. Acids and alkalies.—No acid appears to be formed and faintly acid bouillon cultures are rendered slightly alkaline in the course of a month. Potato cultures are also changed from a normally acid to an alkaline reaction. The liquefied gelatin shows an alkaline reaction to litmus due to the evolution of ammonia as a result of the decomposition changes.

c. Development of odors.—No characteristic odor has been observed in any of the usual cultures. In the cultures made upon cruciferous vegetables each was accompanied by the odor peculiar to the decomposition of that vegetable.

d. Enzymes.—It is evident from the liquefaction of gelatin, and the digestion of the casein of milk that this organism is able to form proteolytic (proteid-dissolving) ferments. Although no attempt has been made to isolate these ferments, the fact that ammonia is evolved and that the course of the digestive changes is so analogous to that of trypsin makes it probable that the enzymes present are related to this class. The ability that the germ has of penetrating the living cell wall of plants also bespeaks for it a digesting enzyme.

Temperature relations.—The maximum temperature for growth lies between 35° and 40° C. At 35° C. growth occurs although considerably retarded. At the higher temperature it is inhibited on agar slopes but a 48 hour exposure does not suffice to kill the germs. The optimum growth temperature is from 25° to 30° C. Growth occurs at 12° C. although much retarded. An exposure of potato and bouillon cultures for three days to temperature ranging between two and ten degrees below zero Centigrade failed to destroy the vitality of the organisms.

Thermal death point.—The thermal death point of the organism varies materially, depending on the length of time the organism has been cultivated under artificial conditions, age of the culture tested, and the temperature at which the culture was grown. In a number of tests, a variation ranging from 44–52° was found when cultures of different origin were exposed for ten minutes. The resistance to heat was greater in a culture recently isolated than in one that had been grown in the laboratory for a year; a similar difference was noted in a young culture compared with a old culture of the same organism.

Resistance toward chemical disinfectants.—A drop of a freshly clouded bouillon culture was added to 10 cc. of the chemical to be tested and bouillon sub-cultures were made at the end of 1, 2, 5, 10 and 15 minutes.

0.5 per cent. solution of lysol killed in 1 minute but 0.25 per cent. solution failed to kill in 15 minutes. Carbolic acid (.625 per cent.) killed in 5 minutes but not in 2 minutes.

Relation toward light.—An exposure of agar plates in August for 15 minutes to the action of direct sunlight destroyed 90 per cent. of all organisms. Similar cultures exposed for 30 minutes in November failed utterly to grow. Exposure for four hours to the action of an electric arc light had no appreciable effect on growth.

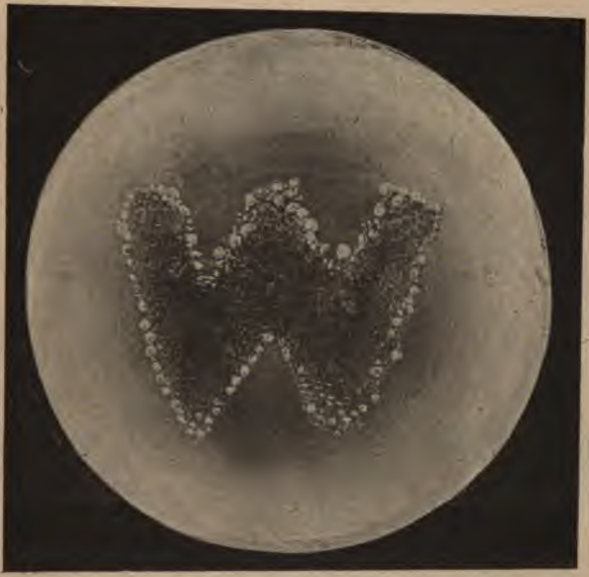


FIG. 7—Showing destructive effect of sunlight on plate culture of *B. campestris.* A thickly seeded plate culture was exposed to direct rays of the sun. On this plate was pasted a letter "W," cut out of black paper, to intercept the sun's rays. Exposure was made for 30 minutes, and then the plate allowed to incubate for a week. Where the culture medium was exposed to the light, the bacteria were destroyed, but under the shaded portion they developed luxuriantly.

Desiccation.—Fresh bouillon cultures were dried at 29° C. on cover slips and kept in darkness for different lengths of time. At the end of 4½ hours, seven out of eight preparations were yet alive. At the end of 21 hours, seven out of eight were sterile. An exposure for 45 hours invariably sufficed to destroy the vitality of the organisms.

Vitality on old cultures.—While the organism succumbs readily in a dried condition, on old laboratory agar cultures it remained alive from four to six months.

Animal inoculations.—Rabbits were inoculated with varying quantities of a fresh bouillon culture of the germ (sub-cutaneous 2½ cc., intravenous, 2 cc., intra-peritoneal, 4 cc.) but no ill effect other than a temporary loss in weight was produced.

ARTIFICIAL INFECTION EXPERIMENTS IN HEALTHY PLANTS.*

Greenhouse experiments.—Mention has already been made of numerous infection experiments made under greenhouse conditions with both cabbage and cauliflower. In these, several score of healthy plants at different stages of maturity were infected in an artificial manner. Usually this was done by puncturing the base of the leaf stock or stem with a needle that had previously been infected with a bacterial culture. In many cases the precaution was taken to disinfect the surface of the plant by chemical agents and the wound made by the injection needle sealed with sterile wax. From the artificially infected plant, diseased tissue was removed and from this the same specific organism was always found.

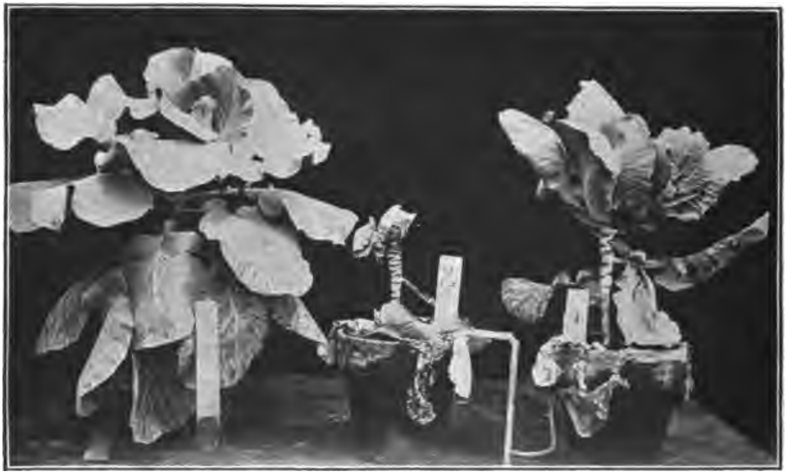


FIG. 8.—Showing effect of artificial inoculation of *B. campestris* into cabbage plants. Nos. 1 and 2 inoculated six weeks previous. No. 3, check plant uninoculated grown under same conditions. The dwarfing effect of the disease is particularly noticeable in this set. No. 1 was inoculated on left side, and the disease was much severer than on the other side. No. 2 was practically killed by the disease.

With but a single exception, every one of these artificial inoculations in cabbage and cauliflower succeeded. The introduction of the disease germ was followed in due course of time by the appearance of the disease, especially in the fibro-vascular bundles. It progressed rapidly toward the apex of the leaf but also worked its way backward into the main stem although more slowly. In inoculating the plant it makes but little difference whether a fibro-vascular bundle is wounded by the inoculating needle or not. The introduced organisms are able to grow in the fundamental parenchyma cells of the leaf, although if inoculated directly into the bundles, they spread faster. Although scores of healthy plants were left as checks side by side with the inoculated plants, in no case but one was there any evidence of the disease being transmitted indirectly from plant to plant. In this exceptional instance, an uninoculated plant became infected by a leaf from a diseased plant coming in contact with a healthy one. By means of this contact, the infective virus passed from one plant to another.

---

*The greenhouse experiments as well as most of the field trials that are detailed below were made at the Horticultural department of the Station. In this connection, I wish to acknowledge my obligation to Professor Goff who has so kindly placed at my disposal the necessary facilities for this part of the investigation; and to Mr. Fred Cranefield of the Horticultural Department, who with my assistant, Mr. Harding, have materially aided me in the details connected with the field and green house work.

In addition to the above varieties of the genus Brassica, infection experiments in the greenhouse were also made in turnips and rape, but these did not acquire the infection.

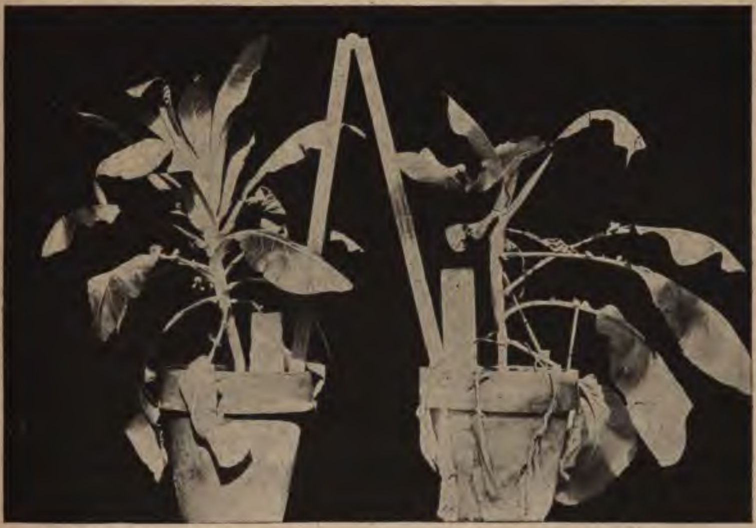


FIG. 9.—Artificial inoculation of cauliflower plants with *B. campestris*.
Both plants grown under identical conditions. No. 1 inoculated with *B. campestris* 45 days before picture was taken. Fourteen days from this date this plant was practically dead from the disease.

Field experiments.— It is not always easy to get at the true condition of affairs by means of greenhouse experiments alone. Moisture, temperature and other factors are often so artificially controlled that a natural development of the disease does not necessarily take place. In order then to obviate this difficulty, extensive artificial infection experiments were made on different kinds of these plants grown out of doors. Over a hundred early cabbage were planted in a field in which no cabbage or related plants had ever been grown. A large part of these were infected artificially and with but a single exception the disease was produced. In many cases the disease was so severe as to practically destroy the plant. Often it was followed by the moist stinking rot, and in some cases the healthy checks also fell a victim to this trouble, but this appearance is not necessarily connected with the bacterial disease here described. Late cabbages were also planted in considerable numbers and infected in part with similar results. The same result was obtained with cauliflower, both early and late plantings developing the disease.

Artificial inoculation experiments were also made under field conditions on collards, broccoli, brussels sprouts, kohl rabi and kale. In all cases the plants inoculated acquired the disease. The kale was much dwarfed and showed plainly the inroads of the disease both in its general appearance and in the individual leaves. Not only were the bundle systems of the leaves quite generally diseased but a general dry rot of the internal tissue also occurred.

In kohl rabi, the fleshy edible part or "head" is interspersed with fibrous strands. In the infected plants the bundles appeared as blackened streaks and often the adjacent parenchyma was rotted for a considerable distance from the fibrous strands.

Inoculations were made in rutabagas and six varieties of turnip. A feeble development occurred in the rutabagas, confined principally to the leaves, while in the turnip in some instances, the disease made small headway, especially in the bundle system after an incubation period of three weeks. In most cases a careful dissection failed to reveal the presence of any diseased tissue. The general appearance of the crown of leaves was vigorous and healthy. One exceptional case showed rotting from internal dry rot caused by development of the disease; another was blackened and affected around the line of the inoculating needle. Turnips on the whole showed only slight susceptibility. It is possible that climatic conditions exert a marked effect in increasing the susceptibility of different plants to the disease, as Pammel notes the serious character of the rot in rutabagas in seasons of heavy rainfall.

APPEARANCE OF NATURALLY DISEASED PLANTS UNDER FIELD CONDITIONS.

Plants closely related to cabbage and cauliflower.—Kale, broccoli, kohl-rabi, brussels sprouts, and collards were planted in close proximity to artificially infected cabbage and cauliflower to see if the disease would spread to them without artificial inoculation. All of these except collards readily acquired the disease both by means of insect wounds and also on the uninjured margins of the leaf. Collards, however, seemed to be less susceptible, as no disease appeared naturally on the leaves.

Cabbage and cauliflower.—The disease is far more severe in cabbage and cauliflower than in any other species of the genus Brassica. It will be well therefore to describe rather fully its appearance in these plants as it occurs in the fields under natural conditions.

The inception of the disease varies somewhat owing to the different methods of infection. Usually it begins on the margin of the leaf at some of the blunt protuberances in which the finer veinlets terminate. The parenchyma in this region appears at first yellow, and if the leaf is viewed by transmitted light, the fine veins are black or brown instead of translucent, as in the healthy state. This blackening of the veinlet is due to changes produced by the bacteria in the fibro-vascular strands. The affection of the leaf at this point soon results in the death of the parenchyma tissue. The leaf turns brown and dries out, becoming leathery and parchment-like in texture. The diseased portion gradually increases in size, usually enclosing or bordering a vein. Sometimes it progresses steadily backward, following the vein until it joins the midrib. Then again, it often breaks out in a lower portion of the leaf without all of the intervening tissue being affected. This condition can be readily discerned by holding the leaf up to the light, in which case the blackened veinlet in the lower portion of the leaf will at once betray the path of the disease even where the cells of the leaf are still green. This apparent break in the continuity of the disease is due to the confinement of the disease bacteria to the bundle systems. The blackened appearance of the veinlets is always characteristic of the disease, but it by no means follows that an absence of this blackening means entire freedom from the specific bacteria. In fact the causal organism can frequently be isolated at a point two or three inches in advance of the darkened tissue.

As the bacilli work their way down the bundle system they reach other strands that branch off from the originally affected one. In such cases, the disease works its way up through these, thus gradually spreading the area of affected tissue. When the midrib of the leaf is affected, it readily enters the main stem, and when once this is invaded, it is impossible to check further progress as it is rapidly distributed throughout the whole plant.

Where the leaf is severely attacked the general nutrition of the same is affected. Often a separative layer is formed at the junction of the leaf and stem, and the leaf falls off leaving the leaf scar with its blackened bundle traces, a condition that is so characteristic as to aid in diagnosis. (Fig. 10.) Where the disease affects the lower part of the stem, it so seriously interferes with the water supply of the upper leaves as to cause them to wilt, especially if evaporation is rapid.

In some cases the disease does not appear first on the margin of the leaf but in close proximity to insect holes. In the early part of the season, the stems of some plants show blackened areas as if the disease had gotten a foothold through the puncture of some insect. The general character of these lesions do not materially differ from those in which the invasion occurs on the edge of the leaf.

Cauliflower heads are not usually affected with the disease even though the plant itself may be badly diseased, but where plant is dwarfed by loss of assimilating surface, the size of the head is much diminished.

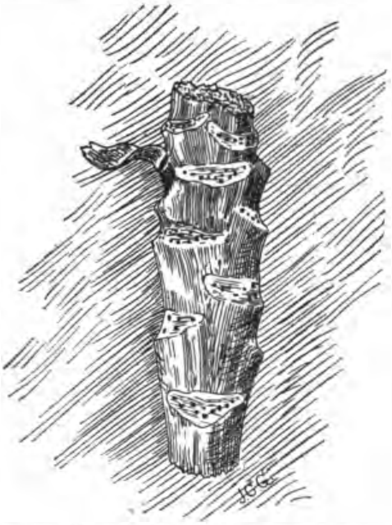


FIG. 10.—Section of the stem of a cabbage plant showing blackened bundle traces in the leaf scar. This appearance on the stem where the leaves have fallen, enables a positive diagnosis of the disease to be made with ease.

In cabbage, however, the heads are frequently invaded, and as infection occurs from below, working its way up into the interior of the stem, the head may often show the disease in an advanced stage on the inside without any evidence on the exterior. In fact this is the usual condition that is found in cabbage held in storage during the winter. Only a single bundle system may show the disease in the stem and yet this is often sufficient to render the whole head worthless. The bacteria work their way up the affected leaf stem, spreading out into the thin leaf blade that is enfolded in the head and which is necessarily in close contact with other leaves that make up the head. This single affected leaf undergoes finally complete disintegration turning into a blackened mushy mass. At this stage, if the heads are cut open vertically, the course of the disease can be readily traced as in Fig. 2.

The exterior of the head often preserves its appearance unchanged while the inner part is completely rotten.

Other host plants.— While we have succeeded in producing the disease to a slight extent in turnips and rutabagas by artificial inoculation, so far only a very few cases of this disease in these plants have come under our observation. While it is possible to infect these plants, the scant growth of the parasite in these tissues shows that they are naturally quite immune. This immunity can doubtless be overcome if certain climatic conditions should prevail. Pammel speaks of the prevalence of his rutabaga rot in 1893 and 1894, and says that the season was an exceptionally rainy one. Possibly under such conditions this disease might prove to be a serious pest.

In one case we have received samples of the white winter radish that were affected with this same trouble, also in a few instances it has been noted in the ordinary summer radish. *B. campestris* was isolated from the diseased tissue in each case.

RELATIVE SUSCEPTIBILITY OF DIFFERENT HOST PLANTS.

So far inoculation experiments have failed on other plants than those belonging to the genus Brassica, and even within the limits of this group there is a great difference in regard to the susceptibility of different species. It is however possibie that under the most favorable circumstances other species of cruciferae or mustard family might be affected. It is of course unwise to draw definite conclusions as to the relative susceptibility of different species from artificial inoculations, as the natural modes of infection may differ with different species. Then, too, the predisposition of different species toward the disease may also be due in part to climatic conditions that are not similar in all cases. Therefore, it is not safe to give final conclusions on this question from the results of only two years' observations. Still, provisionally, the following order of natural susceptibility may be given as shown by the observations already at hand.

The cauliflower is most susceptible, frequently acquiring the disease under conditions where cabbage shows only a mere trace or entire absence of it. Still cabbage is readily affected, as is seen in the Racine district where fields of 10 to 20 or even 30 acres show a badly diseased condition even this year, although the dry weather has retarded the development of the disease. The other varieties closely related to the cabbage and cauliflower such as kale, broccoli, kohl-rabi and brussels sprouts, are quite susceptible to the disease, acquiring it by natural means if the disease germ is present in the surrounding soil.

Collards are apparently the least susceptible to natural infection of those varieties closely allied to this group of the Brassicae.

Turnips, rutabagas, winter radish and species of this character are only slightly susceptible. Under ordinary conditions infection occurs at infrequent intervals and in all probability the disease will not assume in these species a serious aspect except under special conditions.

Relative susceptibility of varieties of same species.—In regard to the relative susceptibility of different varieties of the same species, some data has been gathered particularly with respect to cabbage. Among the growers there is a prevailing notion that the close, hard-headed varieties are less prone to the disease than those having a looser textured head. By far the larger part of cabbage grown for storage or winter consumption is of the

Holland or Danish varieties. Both these flat, firm headed varieties are readily susceptible to it even where imported seed is used.

The red or purple cabbage also contracts the disease with ease; likewise the "fielder kraut" used in the manufacture of sauer kraut. The early maturing varieties such as the early Winnigstadt and early Wakefield succumbed to infection in the Racine fields this year, although the inception of disease was later than with the flat Dutch. In all probability, there is but little difference in susceptibility, all varieties readily yielding to the disease, if the causal organism is once present.

POINTS OF ENTRANCE OF THE DISEASE INTO THE HOST PLANT.

It is very important that the exact method by which the disease organism gains an entrance to the plant be determined, for a rational means of preventing the disease can only be formulated when the source of the disease organism is determined, also its manner of distribution and the way in which the specific organism gains a foothold in the susceptible tissues of the plant. Before discussing these points, it will be necessary to consider certain points relating to the anatomy of the leaf.

Anatomy of leaf as related to this disease.--If a healthy cabbage or cauliflower leaf is examined, especially a young, rapidly growing organ, there will be observed along the roughened margin of the leaf blade, a number of small, blunt protuberances. An examination of these with reference to the veins of the leaf will show that each one of these projections is situated at the termination of a fine veinlet and therefore stands in direct relation to the fibro-vascular strands that make up the veins and ribs of the leaf. A microscopical examination of the edge of the leaf shows that at the apex of these points, there are situated peculiar openings in the epidermis known as "water pores." The function of these structures is to assist in regulating the amount of water in the tissues. The water used by the plant comes from the soil, and by means of root pressure is forced through the fibro-vascular strands to the leaves. In this supply of water is dissolved mineral salts and other substances. Evaporation of the water from the leaf is constantly taking place, and this deficiency is made up by the ascending stream of water known as the transpiration current. Most of this water passes out through the numerous breathing pores that cover the surface of the leaf, but a considerable part also escapes from the fibro-vascular bundles through these water pores.

Conditions necessary to the formation of water beads.—Under ordinary atmospheric conditions, this water escapes in the form of vapor but if the relative humidity of the air is much increased, evaporation is lessened and the water collects in the form of droplets on the tips of these teeth.

This happens especially in late summer when the nights are cool and the air therefore more fully saturated. Under these conditions, if there is an abundant supply of moisture in the ground to induce copious root absorption, the drops are formed almost every night. It should be noticed that this disease breaks out late in the summer, usually not before the first of August. This year little or no evidence of the trouble was noticed until the latter part of the month. This time seems to be closely connected with the atmospheric conditions that permit of the collection or retention of the water in liquid form.

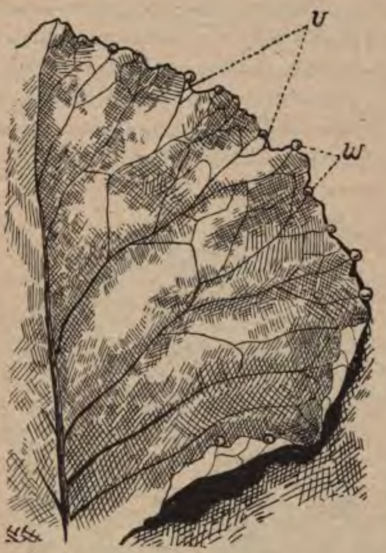


FIG. 11.—Part of a cabbage leaf showing location of water beads (W) and their relation to terminal ends of veinlets (U).

INFECTION OF PLANT THROUGH WATER PORES.

If the leaves of the plant are examined in an early stage of the disease, it is evident that the first seat of the trouble stands in direct relation to the terminal ends of the fibro-vascular bundles. Inasmuch as the water pores already described are permanent openings that are in close connection with the bundle systems, it seems reasonable to suppose that the disease organism is able in some way to gain a foothold in the interior tissues of the plant by first penetrating these water pores. If it once gains entrance, it is able to work its way down the leaf, as is readily demonstrated from natural and artificial infection experiments. If the water pores are evaporating water in the form of vapor, it is difficult to see how the germs would be able to make their way through the stoma or pore and the closely packed cell tissues beneath the opening; but if water is present in liquid form, then the bacteria might be caught in the drop, and under these conditions by virtue of their power of locomotion work their way through the opening into the unprotected tissue below. As the organism is parasitic for plant tissues it would thus be able to obtain a foothold at this point.

Once established its progress would be rapid, as these tissue elements seem especially adapted to its development.

Generally a plant first succumbs at only a limited number of points which are usually on the lower outer leaves, although under favorable conditions for infection numerous water drops may be contaminated. But when the points of infection are compared with the number of water pores on each leaf of the plant, it will at once be noted that the disease is acquired with some difficulty. In all probability this difficulty is not so much due to the mechanical obstructions as to the absence of the disease organism at the appropriate time of infection, i. e., when the water is held in liquid form in the water pores. Under conditions where the disease germs were present in large numbers, a simultaneous infection of a number of water pores might occur.

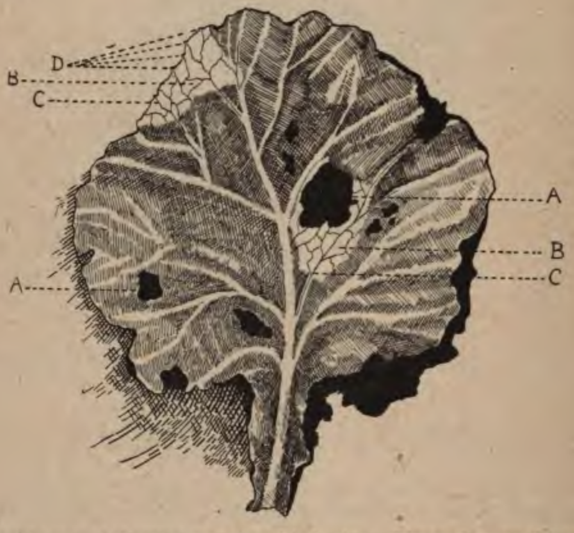


FIG. 12.— Cabbage leaf showing manner of infection. Diseased areas (B) unshaded except blackened mesh of veinlets. (A) Hole eaten by insects. Disease introduced at this point, and spreading backward to main rib. (C) Blackened veinlets affected by disease. (D) Water pores through which disease germs gain a foothold, producing marginal infection.

In order to substantiate the theory here proposed, the following experiments were tried:

Development of B. campestris in exuded water.— An attempt was made to see if *Bacillus campestris* would develop in the water exuded at the pores. This water is rich in mineral matter, especially carbonate of lime. Several cc. of this exuded water was collected by means of a platinum loop and then inoculated with *B. campestris*. From this culture plates were made to determine the number of organisms. The infected water was then allowed to stand for twelve hours, after which time the number of organisms was again determined. The second series of plates showed many more colonies of the specific germ, thus indicating that the bacteria originally seeded were able to grow in the water. These drops of water that collect during the night frequently persist in the morning for some hours, depending upon the state of moisture in the air and the movement of wind currents. During August, even on bright, clear days, drops exposed directly to the sun did not evaporate before 9 or 10 A. M., while those that were protected from the direct rays by leaves frequently remained until near noon.

Infection of plants by artificial inoculation of water beads.— Plants in the field were first abundantly supplied with water in order to induce copious exudation. Early in the morning a number of water drops on several plants were inoculated with a fresh culture of *B. campestris*, care being taken not to wound the tissue in any way, and also to select points that were free from any insect wounds. The plants were then left under natural conditions. No evidence of disease appeared for some time but in the course of two or three weeks, numerous points of infection were noticed on the margin of the leaves that had been inoculated, while those of uninoculated check cabbages kept under similar conditions failed to develop the disease.

This experiment is therefore direct proof of the theory already advanced as to the common mode of natural infection. The disease germs are undoubtedly, in the main, blown about by the air and may either adhere to the surface of the plant in close proximity to the water pores or they may be caught in the drop of water after it is once formed. Under these conditions the organisms would be able to develop, and might establish themselves in the unprotected tissue below the water pore, finally penetrating the terminal ends of the fibro-vascular system.

Infection through broken or wounded surfaces.—Infection can also take place where the external membranes are injured in any way, although this method of introduction is less common than the preceding. Cabbage and cauliflower are very prone to wounds caused by insect depredations and other causes. The leaf is so succulent that the inner tissues of the plant are readily exposed to external influences by the breaking off of the lower leaves which frequently happens in the process of cultivation. Grasshoppers and cabbage worms often make serious inroads. Frequently these insects eat across the smaller vascular elements, thus bringing the more susceptible tissue in direct contact with the air. Nature checks the possibility of infection from this source as quickly as possible by forming a corky layer around the wounded surface, but by artificial inoculation of a broken leaf, it can readily be demonstrated that the disease germ can enter in this way. (Fig. 12, A.)

The first plants that show any signs of the disease are frequently affected in the stem. This occasionally happens even in the seed bed before the plants are transplanted. Such infection in all probability is due to insect puncture, although the insect that thus distributes the contagion has not been observed by the writer.

Can bacteria penetrate uninjured membranes ?—Under natural conditions the inception of the disease can usually be traced to a marginal infection of the leaf or to some insect wound. But the question arises as to the possibility of introducing organisms through the uninjured plant membranes, particularly through the breathing pores of the leaf. Clinically we have failed to find an infected leaf that could not be accounted for on some other hypothesis.

Numerous attempts were made to artificially infect young cauliflower and cabbage by spraying them with cultures of *B. campestris* but these invariably failed, unless the surface of the leaf was scratched very lightly, in which case the disease was easily transmitted.

An interesting case should also be mentioned in this connection. In the greenhouse experiments, one of the artificially infected plants was placed accidently in such a position as to bring a diseased leaf in contact with the leaves of a healthy check plant. Soon the healthy leaf showed signs of the disease at point of contact and the disease gradually spread from this region until the whole leaf became diseased. Transmission from leaf to leaf directly is also seen in the case of the cabbage head. If merely one leaf is affected and the disease works its way out into the blade, it will sooner or later spread from this to contiguous leaves in the head, as in Fig. 2.

SOURCES OF INFECTION.

The original source of the infection can only be conjectured. From all that can be learned in regard to the history of the disease, especially in the Racine district, the trouble is of recent introduction, although in other parts of the country it has been recognized for a number of years.

While we are unable to throw any light on the original source of the disease, a close study of field conditions affords several points of practical interest that bear on the source of infection as it recurs in the affected region.

How does the disease organism live over winter? — In the first place *B. campestris* is unable to form endospores and therefore the organism is much more readily affected than would be the case if these latent spore structures were present. Where fields are affected the causal organism abounds in large numbers. Often the same fields are planted to cabbage year after year, the old rotten stumps and such parts that resist decay being plowed under. Refuse leaves are often carted back on the fields to be used as manure. Under such conditions it is easy to see how the soil of the field might contain a large number of the specific bacteria. Experimentally we have found that it is able to live in bacterial mixtures for some time, thereby indicating that under natural conditions it can withstand such competition.

Cultures have been submitted to a low temperature, below 0° C., for 10-12 days and still sub-cultures grew readily when inoculated from this refrigerated material. Then too the diseased germ has been isolated from decaying material that had been frozen for several months.

The early appearance of the disease in a field usually assumes one of two phases. Either there is a local affection that appears quite early in the season that is confined at first to a few plants, or if the infection is more general, the lower outer leaves are the ones that suffer first.

Disease acquired from infected soil.—Naturally the outer leaves are the oldest and therefore the possibility of infection has been the greatest, but it should be observed that the original points of infection are very frequently the outermost leaves that are often in direct contact or very close to the ground. As long as the soil is moist, the bacteria even though present in the soil could not be disturbed, but nevertheless it frequently happens that the particles are carried by wind to a considerable distance.

The early appearance of the disease on isolated plants in various parts of the field cannot at present be fully explained. In my own experience, I have frequently noted this condition during the present season, but in all cases examined the disease had already obtained such a foothold as to render it impossible to ascertain the primary seat of the disease. Concerning this point, Mr. Hansche informs the writer that he has frequently noted such a condition; and furthermore, he says, that in such cases he has observed a blackened area in the stem. It is asserted by several of the growers with whom I have conferred that this stem infection is produced by the stings of certain insects and that it occurs when the plants are yet in the seed bed. Frequently individual plants show the disease within 10 to 15 days after they are transplanted from the seed bed.

Infection from previously affected plants.—Reference has just been made to the appearance of prematurely diseased plants that occur here and there throughout the field. When once these plants become affected, they serve as foci from which secondary infection spreads. This conclusion was also confirmed as a result of direct experiment. A lot of diseased stalks and cabbage heads were placed near a piece of ground that had been planted to cauliflower and cabbage which had never been so cropped before. In due course of time the cauliflower showed the disease severely, but the cabbage was less affected. In the great majority of cases the natural infection of the healthy plants occurred at the margin of the leaf in the water pores, although some points of infection were directly associated with insect holes. This fully corroborates the view that the affected plants themselves can be the means under favorable conditions of redistributing the disease.

AGENTS IN THE DISTRIBUTION OF DISEASE VIRUS.

Wind currents.—From what has already been said, it is very evident that one direct agent by which the disease is spread is the wind. Whether the disease germ is present in the soil or in decaying plants, the dried baccilli can be carried through the air.

It is of course possible where the disease starts in connection with a wounded or ruptured surface to consider insects and worms as the direct transmitters of contagion, but such can hardly be true where the infection occurs through the water pores. Inasmuch as this is by far the most common gate of entrance for the disease organism, it is highly probable that the disease is disseminated by means of the wind more than in any other way.

The following field conditions may be cited as proof of aerial infection that can not well be explained in any other way: A three-acre field of freshly plowed ground was planted to cabbage this year at Racine, while about ten rods away was another field that the previous year had suffered badly from the disease. (This field is shown in Fig. 1.) The disease is also quite severe this season in the second field. About September 1 the new field began to show some evidence of infection and a close examination showed the disease almost without exception as originating at the water pores. It is of course possible that the plants themselves were diseased in the seed bed but the presumption is much stronger that the disease was spread by wind currents.

Insects.—By tracing the disease to broken leaf surfaces made by insect bites, a strong presumption is raised in favor of the view that insects themselves may function in the transmission of the disease. No experiments have been made to show whether the various insects (caterpillars, grasshoppers, etc.) that infest cabbage and cauliflower are able to transmit the disease. The amount of infection that can be traced to such a source is, however, relatively small and does not begin to compare with the much more important factor of atmospheric dissemination.

INFLUENCE OF CLIMATIC CONDITIONS ON SPREAD OF THE DISEASE.

The varying severity of the disease from year to year on soil that is known to be infected with the disease germ indicates that the spread of the disease is partially controlled by factors other than the specific disease organism itself. In 1896 the disease was very severe in Racine county, while in '95 the losses were less severe. At the present writing there is every indication that the losses will be much less this year than last. In 1896 the season owing to the abundant rainfall was much more favorable for the development of the disease.

The experience of the growers also corroborates this idea that the severity of the disease is dependent in part upon climatic conditions. Usually they expect the disease to progress more rapidly if the moisture supply is abundant, especially if the rains are followed by warm weather. Not only are the conditions that permit infection to occur more likely to prevail during wet weather, but such a condition also facilitates a more rapid

Gaylord Bros.
Makers

growth of the plant which in turn allows the disease to spread more rapidly in the affected tissues.

The following experiments were undertaken under both field and green house conditions that seem to explain the increased severity following wet weather.

RELATION OF IRRIGATION TO DEVELOPMENT OF DISEASE.

Greenhouse experiments.—Rapidly growing cabbage plants were potted and then placed in large boxes filled with sand so that they could be kept copiously supplied with water while others were left as checks under more normal conditions. A number of plants of each set were then infected artifically on April 20, 1896, with a culture of *B. campestris.*

A marked difference very soon appeared in the condition of the over-watered lot compared with those receiving an ordinary supply; the excessively watered plants all showed an exceedingly luxuriant growth, while the moderately watered lot were thrifty but not nearly as large. Coupled with this difference in growth was also a marked difference in the spread of the disease. In the over-watered plants the disease made rapid headway in spite of the more vigorous growth, working its way down the leaf originally inoculated, into and up the main stem, so that the entire plant was quite generally invaded. Fig. 13 shows the condition of these plants after a period of six week's incubation.

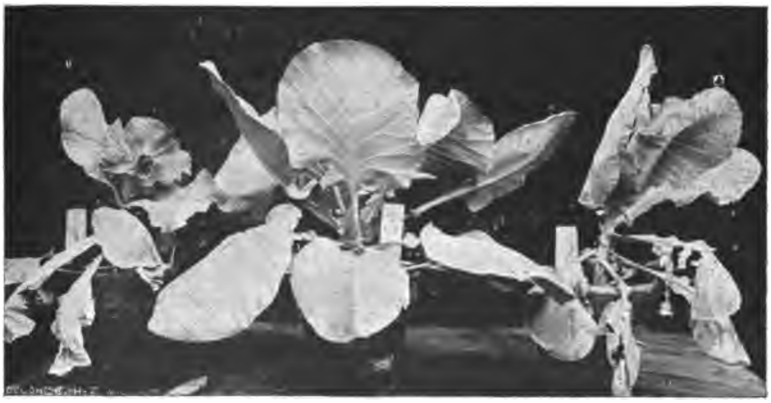


FIG. 13.—Irrigated cabbages showing effect of artificial inoculation. Middle plant (No. 2) shows an uninoculated check. Note its vigorous appearance. Plants 1 and 3 inoculated four weeks before with *B. campestris.* Note dwarfed and one sided manner of growth.

The disease in the moderately watered plants made but slight headway, only a few leaves in any case being affected.

This experiment showed that the more rapid development of the disease was in no way coupled with an unhealthy state of the plant, as the checks of this series were far more vigorous than those that received a less supply of water.

Cabbage seems to be a plant that will stand an amount of water much greater than that needed by most vegetables. If copiously watered a much more succulent and rapid growth occurs. Under such conditions the disease germ spreads more rapidly than where growth is less luxuriant. The relation then to an increased rainfall is that the more abundant water supply favors more succulent and rapid growth of the plant, and in tissues of this character, the disease organism can spread more rapidly than otherwise.

Field experiments.—An irrigation experiment with cabbage and cauliflower was also tried under field conditions. One plot of each species was left as a control lot, being irrigated only when the normal rainfall was insufficient for the needs of the plants. The other lot was subjected to frequent irrigation, although we were unable to supply more water than was required for luxuriant growth. The general results under these field conditions corroborated those of the previous experiments and showed that the disease progressed more rapidly in the faster growing plants. An abundant supply of moisture in the ground may also influence the susceptibility of the plant to the disease, as a rapid excretion of water through the water pores can only happen when the roots are actively absorbing. When the ground is dry the amount of water absorbed is less than the needs of the plant; consequently moisture does not gather at the water pores even though the atmospheric conditions favor such process. Such were the conditions this year. Late in August the nights were very cool but as the ground was excessively dry, no perceptible amount of water was excreted. After a thorough irrigation the plants in the same field showed an abundance of water drops. As the infection of the plant occurs mainly when the water drops are present on the leaves it is more liable to contract the disease when soil moisture is abundant.

RELATION OF THE PARASITE TO HOST.

This relation is somewhat peculiar. The disease germ usually gains a foothold in the tissues of the leaf at the margin and from here it works its way through the plant by the way of the fibro-vascular bundles. An examination of a cross section of an affected leaf in the early stages of the disease will show blackened specks in the bundle strands. (Fig. 14.) If a thin section is examined microscopically, it will be noted that the disease is confined usually to the xylem or woody portion of the bundle. The cambium and bast regions of the bundle are usually free, but in the xylem the large vessels are the tissues that seem most susceptible. The cavity of these thick walled tubular vessels are frequently clogged completely with the accumulated growth of bacteria in the cells. Under the microscope, these bacterial masses assume a yellowish brown color and the walls of the cells are also deeply stained so that the diseased tissue is easily recognized. Besides the large vessels already mentioned, the smaller, thinner walled wood parenchyma cells that are interspersed among the larger mechanical elements are often diseased in a similar way.

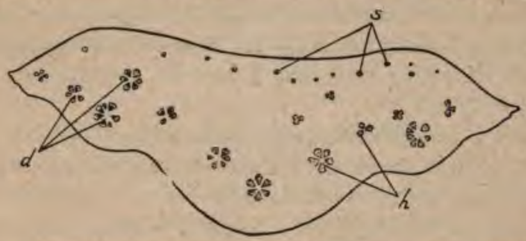


FIG. 14.—Cross section of leaf slightly magnified showing distribution of fibro-vascular bundles in same. Larger bundles situated on lower side of leaf. Those on right side healthy (h); those on left diseased (d). On upper margin a number of smaller secondary bundles (s).

Why it is that the bacteria are able to develop so luxuriantly in these tissues and not spread to contiguous tissue elements is a matter of considerable interest?

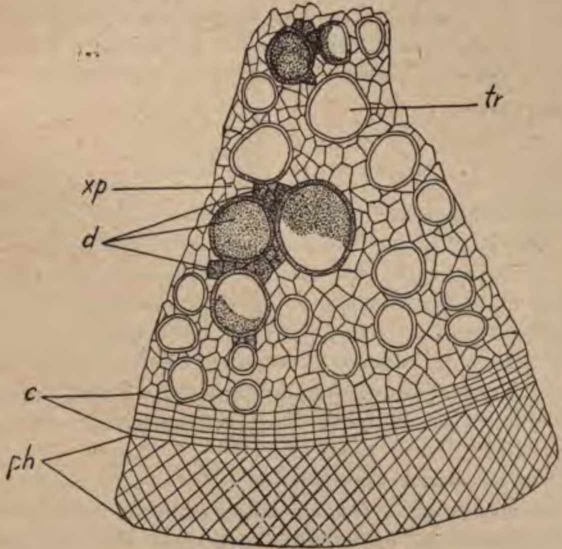


FIG. 15.—Highly magnified diagrammatic section of single fibro-vascular bundle showing histological elements affected by disease. Each bundle is made up of three kinds of tissue, outer bast region (ph), middle cambium or growing zone (c), and the thinner part of the wedge or woody part of the bundle (xylem). The disease attacks primarily the xylem part especially the large circular vessels (tr). The bacteria spread through these tubular vessels often clogging them up completely as at (d). Where development is rapid, the bacteria force their way out into the thin walled wood parenchyma cells that surround these large vessels of the xylem.

It is possible that it might be due to the chemical reaction of these elements, or they may work their way through these tubular channels for largely mechanical reasons. The cavity of these cells is supposed to be devoid of food materials other than water but their walls are extremely thin between the thickened rings, and it is possible that the necessary nourishment may be received from the contiguous parenchyma cells that are rich in protoplasm. In this event, these large vessels serve as a highway along which development can follow the lines of least resistance, while the neighboring cells are the fields that furnish the provender for the support of the invading army.

With regard to the possibility that the choice of these cells as a seat of development is due to the chemical reaction, it may be said that the organism in pure culture shows considerable degree of toleration toward both acid and alkali, and therefore it is improbable that it is confined to any special tissue on account of the chemical reaction of the cell.

Development also occurs in the parenchymatous tissue. In these cells it is prone to imbed itself in the cell plasm. Where the cell cavity is not entirely filled with protoplasm, it frequently follows the protoplasmic strands, so that these are rendered readily visible by the micro-organisms imbedded in them. By taking care in inoculating succulent leaf stalks it is possible to introduce the disease germ into the parenchyma without wounding the fibro-vascular bundles. Under such conditions, the host contracts the disease although the spread of the malady is much less rapid. This indicates that the acidity of these tissues is not sufficient to prevent bacterial development.

TREATMENT OF THE DISEASE.

Curative measures are of little avail in a disease that develops entirely within the host plant as any disinfectant that will destroy the disease after it has once established itself will also injure the susceptible tissues of the host. About all that can be done with a disease of this sort is to prevent it from gaining a foothold. In the case of plants, however, it is sometimes possible to remove the diseased tissues before the malady has spread throughout the whole plant, and in this way to limit the development of the disease both in the individual host and in its distribution from one plant to another.

Destruction of disease germ outside of host.—B. campestris is not an especially hardy organism. It is a non spore-bearing form, and therefore unable to withstand an unfavorable enviroment like the spore-bearing bacteria. Sunlight and drying both exert a powerful effect on the vitality of the germ, but these agents cannot be relied upon to destroy the diseased tissue. Sunlight is only efficient when it comes in direct contact with the disease organism. Where the diseased leaves and stalks are allowed to dry in the fields, the bacilli are buried in the dried tissue, and are not therefore subjected directly to the action of the sun.

Much refuse material containing the seeds of the disease is always left on the ground after the crop is harvested. While it would undoubtedly be advantageous to get rid of this material, if it could be done without much expense, still I do not think that the benefit derived from removing this refuse would compensate for the trouble involved unless the method was universally followed throughout an affected section.

The disease is undoubtedly propagated in any section by the custom of planting the same field to this crop year after year. In this way, the disease germ is brought in contact with a susceptible host in which it can develop. If rotation of crops was more generally practiced, the disease germs present in the soil would gradually be eliminated. Great care should be taken in selecting the location of the seed bed. Under no circumstances should it be placed in fields that have been infected with the disease.

PREVENTING THE INTRODUCTION OF THE DISEASE GERM INTO HOST.

1. *By retarding formation of water beads.*— The varying severity of the disease from year to year indicates that either the causal organism varies in virulence or that the host plant is much more liable to contract the disease one season than it is another. Experiments, as well as field observations, show that the varying intensity of the trouble is correlated with climatic changes. In seasons having a copious rainfall, the disease is very much more severe than otherwise. The reason for this is, that as the disease germ gains an entrance into the plant by means of the water drops formed at the water pores, conditions that favor the collection of this water in liquid form predispose the plant to the attack of the disease germ. Copious supplies of soil water permit an increased evaporation from the leaves; hence if the humidity of the air favors the deposition of this water in liquid form then climatic conditions favor infection.

Cabbage is preeminently a water-loving plant, and does well on soils containing an abundance of moisture but care should be taken not to plant the crop on too wet soils as the increased luxuriance in growth and increased readiness to infection through the leaves renders the plant more susceptible than when grown on soil containing a lower water content. Ordinarily the supply of soil moisture is not directly under control but where irrigation is practiced, care should be taken not to irrigate when the atmospheric conditions prevent the escape of the moisture from the leaves in vaporous condition.

2. *By preventing insect wounds.*— While insects do not function as the main agents in transmitting the virus of the disease, they are undoubtedly of some importance. It seems very probable that in the seed bed particularly, insects may cause the most damage. If this should prove true, it ought to be a relatively simple matter to check such ravages where the area to be covered is as limited as it would be in this case.

CHECKING DEVELOPMENT OF DISEASE ATFER INFECTION.

Inasmuch as *B. campestris* generally establishes itself in the plant through the water pores, and as the period of incubation is considerable from the first inception of the disease until it has worked its way down into the main stem, it is possible to check the disease in its incipient stages by an early removal of the affected organ. The diseased tissue can be readily determined by examining the cross section of the leaf stalk. If blackened near the union of leaf and stem, the disease organism has already entered the main stem. When this is the case, nothing can be done to further check its progress. Such plants should be pulled up and destroyed.

If the field is examined at an early date, and the presence of the disease determined, the removal of the affected leaves at this time is an easy matter. Such diseased plants and leaves should not be thrown on the ground, but must be carted away from the field and destroyed, so as to prevent further infection.

Such a method of treatment necessarily consumes some time, but a cheap hand can do the work effectually. With a crop worth from $75 to $150 per acre considerable labor can well be expended if attended with any degree of success.

The amount of labor necessary to carry out this restrictive measure will vary with the intensity of the disease, but a man could easily cover several acres a day.

The following field notes are submitted as showing the effectiveness of this method of treatment.

On the Horticultural grounds at the University, cauliflower was planted on soil that had borne a similar crop the previous year, and one which was somewhat affected with the rot. This field was allowed to develop in the usual manner until September of this year. By the first of the month, the patch began to show evidence that the disease was pretty generally distributed. At this date it was divided into four sections and from alternate sections the attempt was made to stop the disease by removing the affected leaves. The other two sections were left under natural conditions and no attempt was made to check the spread of the malady. The result of this experiment was that the disease was held completely in check. Several plants became infected subsequent to the removal of the diseased leaves, but by removing all of these later the further progress of the disease was brought to a standstill.

The continued spread of the disease in the uncontrolled sections showed that the disease organism was being thoroughly distributed and therefore the failure to spread was not due to absence of disease virus.

Another experiment was also carried out on a larger scale under commercial conditions. A field of about three acres of cabbage near Berryville, Wis., was noted that had been planted on new ground that had never had

Gaylord Bros.
Makers
Syracuse, N. Y.

cabbage on it before. When first observed on September 1st, of this year, the cabbage rot was just beginning to make its appearance. In some cases where the plants were small the disease had established itself in the stem, but in the majority of cases only individual leaves were affected. At our suggestion, the owner decided to remove all diseased leaves and badly affected plants in order to see whether the progress of the trouble might not be retarded. The result of this was that the repressive measures used kept the disease well in check. The patch was only fifteen rods distant from another field that was very severely affected, and of course the seeds of the disease were continually being distributed by means of the wind. The disease made but slow headway as the season was unusually dry. Yet under the same atmospheric and soil conditions, in another large patch in which no repressive measures were attempted the disease developed severely.

LANE MEDICAL LIBRARY

To avoid fine, this book should be returned on
or before the date last stamped below.

Y31 Russell,H.L.
W8E1 Bacterial rot
no.65 bage and allied

NAME